Title

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Abstract

Rising interest rates can create "interest rate lock" for homeowners with fixed rate mortgages, who can hold onto their low rates as long as they stay in their homes but would have to take on new mortgages with higher rates if they moved. We show mobility rates fell in 2022 and 2023 for homeowners with mortgages, as market rates rose. There were no such declines for homeowners without mortgages or for renters, and the decline is not explained by changes in home values. Overall, our estimates imply that rising interest rates reduced mobility by 15% for households with mortgages.

Keywords: mortgages, mobility, interest rates, housing lock
JEL Classification: G21, G51, J61, R21, R23

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1 Introduction

The traditional 30-year, fixed-rate, non-assumable mortgage that is used for most home purchases in the United States is an unusual instrument. Because there are no pre-payment penalties, borrowers can and very often do re-finance their mortgages to take advantage of declines in interest rates. Thus, the rate is in practice adjustable downward. But this is asymmetric. When rates rise, borrowers are protected – the rate does not adjust up – so long as the borrower remains in the house. Mortgages cannot be assumed by new buyers nor rolled over into different properties. Should the original borrower wish to move to a new house, he or she must obtain a new mortgage at the market rate.

This feature can create a very strong fixed cost of moving for those holding mortgages at rates lower than the currently prevailing rate. Consider a homeowner who took out a fixed rate mortgage in 2016 at 3.5%, a typical rate for that year, and who still owes $200,000 as of 2023. Suppose that circumstances in her life make it desirable for her to move to a different house of equal value, and that her credit score is excellent, so lenders are eager to offer her a new mortgage at the now-prevailing rate of 7%. Making the move will increase her monthly payment by 38%, cumulating to over $110,000 over the remaining life of the loan.[1]

This is a pure cost of moving, one that can be avoided entirely by remaining in the original house. It thus discourages mobility, and can lead a borrower to avoid moves that would otherwise be desirable (for example, for a new job opportunity).

Interest rates were on a long-term downward trajectory from the early 1980s until the COVID pandemic, so this aspect of mortgages was not empirically relevant for most homeowners for many years. However, between January 2021 and November 2022, average mortgage rates rose from 2.65 to 6.95%, a more than four point increase. Rates are now higher than at any point since 2002. We show below that nearly all current mortgage holders have rates

[1] To hold as much constant as possible, this calculation assumes that either the new or old loan would be paid off in equal monthly payments over the 23 years remaining of the original loan's term. The present value of the additional payments is $55,000 with a discount rate of 7% or $76,000 with a discount rate of 3.5%. If the new mortgage is paid off over 30 years rather than 23, the nominal monthly payment rises by only 26%.

much lower than would be available today, as even older mortgages are likely to have been refinanced since.

We study the effect of rising interest rates on mobility. We show that mobility rates of homeowners with mortgages have fallen dramatically since 2021, and that this has been concentrated among mortgages originated when rates were substantially lower. There has been no corresponding change in mobility rates for renters or homeowners without mortgages. We use a hazard analysis to show that each percentage point increase in the currently prevailing rate above a borrower's origination rate is associated with a 5.5% decline in the quarterly mobility probability.

Previous studies have documented the effects of mortgage lock during earlier periods.[2] Quigley (1987, 2002) study lock-in during the 1980s and 1990s, building on the household relocation models in Hanushek and Quigley (1978) and Venti and Wise (1984). Ferreira et al. (2010, 2011) find substantial rate lock-in effects during the 2000s, and also show large effects of negative home equity. More recently, Fonseca and Liu (2023) show that mortgage lock-in reduced labor mobility during the 2010s.[3] To the best of our knowledge, this is the first paper to estimate the effects of rate lock-in during the period of rapid rate increases in 2022 and 2023. The recent time period is interesting because the increase in interest rates is much larger than has been seen in recent decades and was largely unexpected, creating a new opportunity to measure interest rate lock.

Beyond the time period, several methodological differences set us apart from the previous literature. First, we use a hazard framework, which we think is important to control for the fact that moving likelihood is not constant over time. In particular, moving rates are higher for people with short tenures in their homes, which can be correlated with interest rates; the duration controls in our hazard model are important to control for this. Second, a central part of our analysis is the comparison of households with mortgages to those without, i.e.,

[2]A large literature studies the effects of negative equity on mobility, a different channel than the one we study. See Andersson and Mayock (2014), Bernstein and Struyven (2022), Foote (2016), Brown et al. (2019).

[3]Fonseca and Liu (2023) also explore several important implications of rate lock which we do discuss, for example the impact on labor markets.

renters and households who have paid their mortgage off.[4] This allows us to guard against the possibility that our mobility rate estimates, which are identified largely from time-series variation, are not capturing other factors that may be correlated with the change in interest rates. Third, we use high-frequency credit registry data to measure mobility for a large and representative population, similar to the data in Fonseca and Liu (2023).

Although the current high-interest-rate regime been in effect for less than two years, it is already having quantitatively important consequences for aggregate mobility rates. We show that the decline in average moving probabilities since 2021 that is attributable to interest rate lock sped up the secular decline in mobility rates by as much as one and a half years. As many previous authors have noted (e.g. Molloy et al., 2016; Fonseca and Liu, 2023), increases in moving costs and declines in mobility have the potential to add substantial friction to the free flow of workers to job opportunities in the labor market and slow recovery from recessions.

Interest rate lock also has consequences for lenders. Insofar as homeowners respond to interest rate increases by reducing mobility, this contributes to the asymmetry between interest rate changes and time-to-mortgage-payoff, reducing mortgage payoffs at exactly the times when it is most costly to the lenders for the mortgages to remain outstanding. We show that, under reasonable assumptions, interest rate lock reduced the average interest rate on outstanding loans in 2023Q1 by 8 basis points, relative to what it would have been had mobility been unaffected.

The remainder of this paper is organized as follows. Section 2 discusses institutional details and presents a simple calculation of the contribution of interest rate lock to the cost of moving. Section 3 describes the data we use to obtain high-frequency measures of mobility rates. Section 4 presents our main empirical strategy. Section 5 presents the main results and robustness analysis. Section 6 concludes.

[4] This strategy builds on similar approaches taken in earlier papers, for example Aladangady (2017) and Atalay and Edwards (2022) on housing wealth effects, and Chaney et al. (2012) on corporate investment.

2 Institutional Details and Motivating Framework

U.S. mortgages come in two flavors — fixed rate (FRM) and adjustable rate (ARM). ARM mortgages have rates that adjust, often with a lag, to changing market rates. FRM mortgages have rates that are fixed at origination, sometimes with a (pre-established) discount early in the mortgage's life. The vast majority of mortgages issued in the last 15 years have been FRMs.[5]

Nearly all U.S. residential mortgages, both ARM and FRM, are securitized by the home, are not assumable by a new buyer, allow for prepayment without substantial penalties, and must be paid in full if and when the home is sold. These features create what we call "interest rate lock" for FRM borrowers.[6] A homeowner who wishes to move must assume not only the difference in prices between the old and new house, but also a new interest rate. If market rates are higher at the time of the move than at the time of the original mortgage's origination, his or her payments will go up even if the size of the mortgage is the same. This is effectively a capital loss.[7] However, unlike with other kinds of debt, in this case the homeowner can avoid the capital loss by remaining in the old house. He or she thus has an incentive not to move. This distortion can lead to inefficiencies, if homeowners are unable to pursue new job opportunities in different locations or to downsize when life circumstances make that appropriate.[8]

Figure 1 shows the path of mortgage interest rates since 2013. Rates oscillated between about 3.5% and 5% between 2013 and 2020, falling below 3% in the wake of the COVID crisis. In early 2022, however, they began rising sharply, following Federal Reserve monetary policy tightening, and they have been above 6% since October 2022.

We overlay on this graph the 25th, 50th, and 75th percentiles of interest rates on outstand-

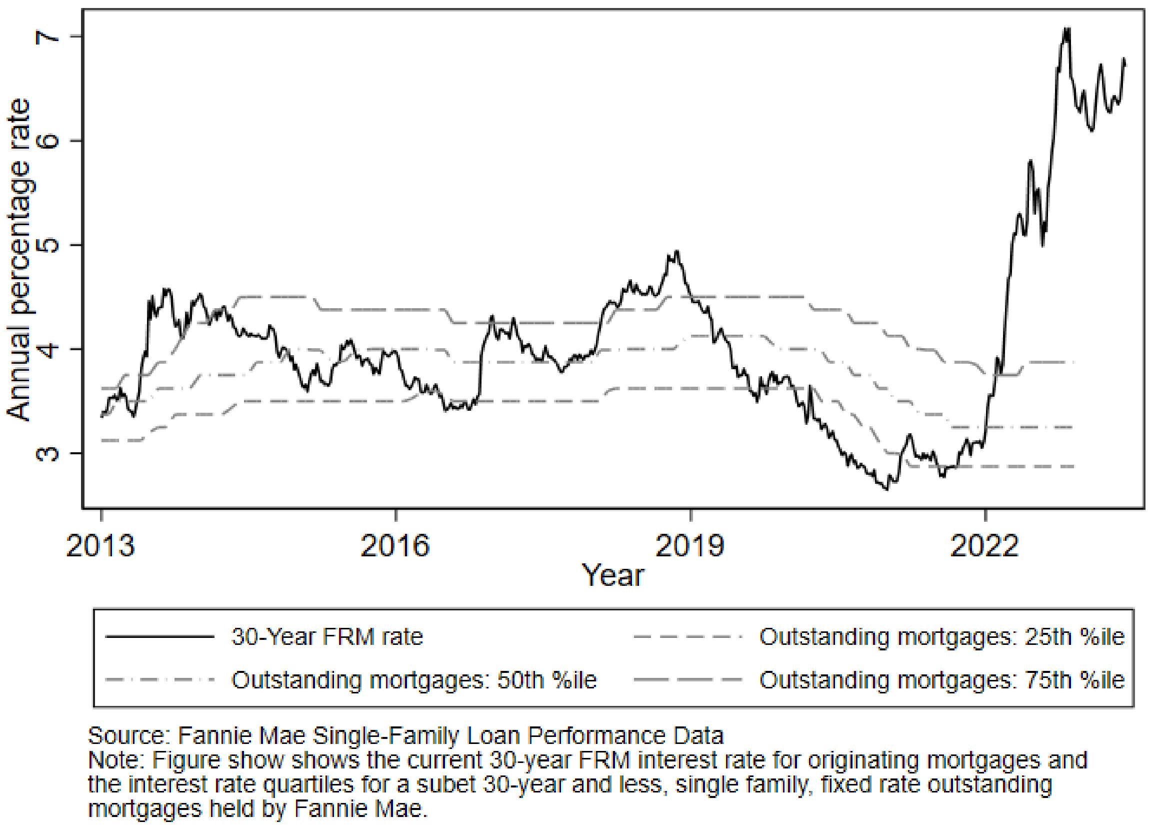
[5] The ARM share of applications fell from about 1/3 in 2004-5 to 5% in 2009, and has been below 10% nearly all of the time since (Goodman et al., 2023).

[6] A conceptually distinct type of housing lock arises when when the market value of the house is insufficient to pay off the remaining balance on the mortgage – when the borrower is "underwater." This has been studied more - see, e.g., Ferreira et al. (2010).

[7] Bond values rise when rates increase and fall when they decrease. Borrowers are short bonds, so take losses and gains, respectively.

[8] Similar inefficiencies have been noted due to property tax rules that tie the tax bill to the purchase price (Ferreira, 2010) and to rent control regimes that limit rent increases for incumbent tenants (e.g., Munch and Svarer, 2002). A longstanding policy conversation points to declining mobility rates as an indication of reduced dynamism of the U.S. economy (e.g., Molloy et al., 2016)

Figure 1: Mortgage Interest Rates and Rate Gaps



Notes: Figure shows the current 30-year interest rate for originating FRM mortgages as well as quartiles of interest rates on outstanding 30-year or less, single family FRMs held by Fannie Mae. Outstanding loan interest rates are computed from the Fannie Mae Single-Family Loan Performance Data, which excludes loans originated before 1999.

ing FRMs, calculated from the Fannie Mae Single-Family Loan Performance sample.[9] These are based on the distribution of rates across loans issued at many different times, and as such move much more slowly than does the current rate series, generally with a lag. For example, the decline in rates that began in 2018 does not show up in the outstanding loan rate distribution until 2020. A consequence is that the distribution of rates on outstanding mortgages in 2022 and 2023 largely reflects the pre-2021 low-rate environment. Even the 75th percentile of that distribution was below 4% at the end of 2022, 2.5 percentage points below the rate then being offered on new mortgages.

The cost of taking on a new mortgage is directly related to the gap between the currently offered rate and the rate on the existing mortgage. To fix ideas, consider a homeowner with a mortgage that was taken out at the past at some annual rate R_0, with remaining principal P and m monthly payments remaining in the term. Suppose that the homeowner is considering moving to a new house of identical value, and converting all of his/her remaining equity into a down payment. This means that he will need to take out a new mortgage with principal P at new interest rate R_1. For simplicity, assume the remaining term will be the same, m months.

Using standard amortization formulas, the monthly payment for the existing mortgage is $P * f(R_0)$, where $f(R) \equiv \frac{R_0/12}{1-(1+R_0/12)^{-m}}$, while the monthly payment for the new mortgage will be $P * f(R_1)$. Note that $f(\cdot)$ is increasing in R, so payments increase with the new mortgage. With discount rate δ, the present value of the cost of trading the former obligation for the latter is

$$P\frac{f(R_1) - f(R_0)}{f(\delta)}.$$

This can be substantial. An increase from $R_0 = 3.5\%$ to $R_1 = 7\%$ would, with a discount rate of 3.5%, raise the present value of future payments by 38%.[10]

An increase in rates can also cause lock-in through a second channel. Rising rates can

[9] https://capitalmarkets.fanniemae.com/credit-risk-transfer/single-family-credit-risk-transfer/fannie-mae-single-family-loan-performance-data

[10] We have neglected the possibility that the term could be extended with a new mortgage. This would lower the monthly payment, but (so long as $\delta \leq R_1$) not the present value of the stream of payments.

reduce the value of homes, by increasing the payment that a prospective buyer would need to pay to finance a mortgage at any given value or indirectly via negative effects on overall economic activity that reduce demand in the housing market. This could push homeowners "underwater," owing more on their mortgage than they could obtain by selling, and thus reduce their ability to finance a move. In the present episode, the rise in rates has not been associated with a large decline in average values. Moreover, our analysis builds in two features that enable us to distinguish interest rate lock from value effects: We compare the change in mobility for mortgage-holders to that for non-mortgage-holding homeowners, and we control directly for the change in home values in the local area.

3 Data

3.1 Credit Registry Data

Our main data source is the University of California Consumer Credit Panel (UC-CCP), developed and maintained by the California Policy Lab at the University of California. UC-CCP is a nationally representative credit registry containing longitudinal information on a 2% random sample of U.S. individuals with a credit history. Quarterly data on households and credit accounts are constructed from records compiled by one of the major credit reporting agencies. Address information includes the zip code of residence, which is updated shortly after moves as financial institutions stay in close touch with their clients.[11] For this reason, the UC-CCP is ideal for measuring mobility among households with a credit history, a group which includes the mortgage borrowers who are our focus.[12]

We identify all unique mortgage originations, identified by the borrower, origination date, and principal amount. We measure whether and when thereafter the borrower relocates to

[11]To reflect the possibility that people may not move into a newly purchased house immediately after the mortgage is originated, we identify the house location based on the purchaser's location two quarters after origination, and consider only moves after that point.

[12]See Holmes (2021) and Holmes and White (2022).

another zip code, focusing on the first ten years (40 quarters) after origination.We also measure whether the mortgage is closed, which could happen without a move in the case of refinancing. We limit the sample to mortgages originated between the first quarter of 2014 and the third quarter of 2021, after which interest rates rose most rapidly.

Our sample of mortgage originations includes both new purchases and refinancings. We consider each as the beginning of a new spell, one that ends if and when the household moves out of the ZIP code. We think it is important to consider both new purchases and refinancings, as the latter make up a large share of the market. However, including both means that a single household-ZIP combination can be represented by several overlapping spells - one begins when the home is purchased, and another begins when it is refinanced. In some analyses we select one at random to avoid dependence among observations.

We proxy for a mortgage's interest rate with the market rate at the time that a mortgage was originated. This ensures that our rate gap measures are not based on borrowers' creditworthiness, and avoids substantial measurement error in mortgage rates computed from credit records. Quarterly market rates come from Freddie Mac's Primary Mortgage Market Survey and pertain to 30-year FRMs. Our primary measure updates to the new market rate whenever a mortgage was refinanced, but we construct a second measure that preserves the original mortgage's origination rate as well.[13]

We construct a second panel of households who do not have a mortgage. Here, "spells" begin when the household moves into a ZIP code, and end when the household leaves it. Households that have mortgages at any time during this period are excluded. We divide this panel into separate renter and owner subsamples. Renters are households not identified by the UC-CCP as homeowners who do not obtain a mortgage at any point while living in a ZIP code Non-mortgage owners are defined as households who do not begin their stay with a mortgage, and are not renters, but have had a mortgage at some point previously while living at that ZIP code. Although there is probably some misclassification between renters and owners without

[13]For spells beginning with a refinance, the "origination" rate is that for the date of the focal refinance origination, and the updated rate may differ if the homeowner later refinanced again.

a mortgage, we are not too worried about it since we find similar results for both groups. The more important distinction is between households with and without a mortgage which we think is measured well.

3.2 Other Data Sources

We obtain ZIP level house price indexes from Zillow. Using these, we calculate the change in house prices in a ZIP code since a mortgage was originated.

3.3 Summary Statistics

Tables 1 and 2 present summary statistics for the main analysis sample. In Table 1, we present statistics at the mortgage level. We have over 900,000 mortgages in our sample. New purchases are 36% of the originations in our sample, with the remainder being refinancings. The average interest rate is 3.9%. 57% of mortgages are closed within five years of origination, about half due to moves out of the zip code and half to refinancings.

Table 1: Summary statistics (mortgage level)

	mean	p50	sd	N
New Purchase	0.359	0	0.480	915177
Credit Score	745.822	759	66.529	915177
Duration - Quarters	30.140	30	6.116	915177
Principal Balance	2.36e+05	191468	2.3e+05	915177
Origination Rate	3.916	4	0.309	915177
Female	0.358	0	0.480	915177
Male	0.419	0	0.493	915177
Age at Origination	46.850	46	13.933	915177
Moved - 5 Years Since Origination	0.283	0	0.450	915177
Closed - 5 Years Since Origination	0.565	1	0.496	915177
Ever Move	0.387	0	0.487	915177
Ever Close	0.744	1	0.436	915177

Notes: Statistics pertain to mortgage sample. Where a household takes out multiple mortgages while in the same ZIP code (i.e., when an initial purchase mortgage is refinanced), one is selected at random. N=915,338.

Table 2 shows statistics for the mortgage-by-quarter panel, with nearly 30 million quarterly observations. We construct this as a panel that begins when the mortgage is originated and continues to the end of our period in 2022 or for 10 years, whichever is sooner, even if the household moves out of the ZIP code during this period. About 15% of our quarterly observations have moved, and in 31% of the mortgage has been closed. The average gap between the mortgage rate in effect for the mortgage and the current rate is 0.2 percentage points, but for the 51% of mortgages with a positive gap it averages 1.2%. Table 3 shows parallel statistics for our panel of renters and non-mortgaged-owners.

Table 2: Summary statistics (mortgage-by-quarter panel)

	mean	p50	sd	N
Origination Year	2016.222	2016	2.577	26943151
New Purchase	0.336	0.000	0.472	26943151
Move Zips	0.016	0.000	0.125	26943151
Closed	0.315	0.000	0.464	26943151
Rate Gap (positive)	0.544	0.002	0.914	26943151
Rate Gap (negative)	-0.314	0.000	0.452	26943151
Rate Gap (unconditional)	0.230	0.002	1.175	26943151
Origination Rate	3.851	3.880	0496	26943151
Credit Score	761.807	785	82.279	26943151
Cumulative Revolving Credit	1.07e+06	5.5e+05	1.5e+06	26943151
Balance	1.63e+05	1.3e+05	1.9e+05	26943151
Log ZHVI Change	0.205	0.156	0.185	26943151
Positive ZHVI Change	0.957	1.000	0.203	26943151

Notes: Statistics pertain to mortgage panel, with one observation per mortgage per subsequent quarter (for up to 40 quarters from origination). Where a household takes out multiple mortgages while in the same ZIP code (i.e., when an initial purchase mortgage is refinanced), one is selected at random. N=25.5m mortgage-quarter observations on 915,338 mortgages.

Table 3: Summary statistics (renters and cash buyers)

	mean	p50	sd	count
Renter	0.774	1.000	0.418	10160075
Move	0.064	0.000	0.244	10160075
Rate Gap (positive)	0.458	0.000	0.863	10160075
Rate Gap (negative)	-0.320	-0.108	0.440	10160075
Rate Gap (unconditional)	0.137	-0.108	1.110	10160075
Origination Rate	3.932	3.950	0.594	10160075
Log ZHVI Change	0.146	0.088	0.170	10160075
Positive ZHVI Change	0.844	1.000	0.362	10160075

4 Empirical Strategy

At its simplest, our analysis compares the mobility rates of households facing different interest rate gaps between the fixed rates on their long-established mortgages and the current market rate. But there are several challenges to the interpretation of this comparison as reflecting the causal effect of rate lock.

One difficulty is that households become less likely to move as they stay longer in a particular location (Howard and Shao, 2022). Since interest rates were falling for much of the 2000s, and not all households refinanced, longer-tenured households faced smaller interest rate gaps in 2023. Their longer tenure also made them less likely to move. Estimates which do not control for housing tenure are likely to be biased towards zero.[14] To deal with this issue, we implement a Cox proportional hazard model in which rate gap effects are estimated relative to a flexible baseline hazard by tenure. Identification thus comes from contrasts between households of similar tenure facing different rate gaps (e.g., because they purchased at different times, so face different conditions at any fixed tenure).

A related concern is sample attrition coming from refinancing. If households that refinance leave the sample, it will become quite unrepresentative at higher tenures, particularly following the very low rate period in 2019-2020. To ensure that this does not affect the results, we retain households in the sample after they refinance their mortgage, until they move out of the original ZIP code.[15]

Even so, refinancing may be endogenous, as households that anticipate moving soon are less likely to refinance. This would lead to a spurious negative relationship between a household's mortgage rate and its propensity to move. We use the methods developed in Palmer (2022) to instrument for a household's current interest rate using the rate prevailing at mortgage origination. We also study refinancing loans and purchase loans separately since we think it is particularly plausible that origination rates are unrelated to unobserved heterogeneity in

[14]Thanks to Greg Howard for a helpful conversation about this issue.

[15]Another approach to this would be to estimate a competing risks model, where mortgages "fail" either when the household moves or when they are refinanced. We defer this to future work.

moving plans for new buyers.

Last, one might worry that omitted variables that are correlated with interest rate movements affect household mobility. An obvious candidate is the COVID-19 pandemic. Interest rates rose exactly when the U.S. economy was recovering from the pandemic, which might have affected mobility directly. Our strategy here is to compare mortgage-holders to other households that also were experiencing any pandemic effects but were not directly affected by interest rates. We show that mobility of households with mortgages is much more sensitive to interest rate gaps than is the mobility of renters and mortgage-free homeowners. Robustness checks controlling for time-varying housing market variables give us further confidence that omitted macro variables are not driving the results.

The large and unexpected nature of the 2022 interest rate shock also helps with identification. Estimates from earlier years might be confounded by slow-moving macroeconomic variables, like demographic change or secular trends in migration. Event study graphs show large changes in mobility, right at the time that rates went up, exactly for the groups we expect.

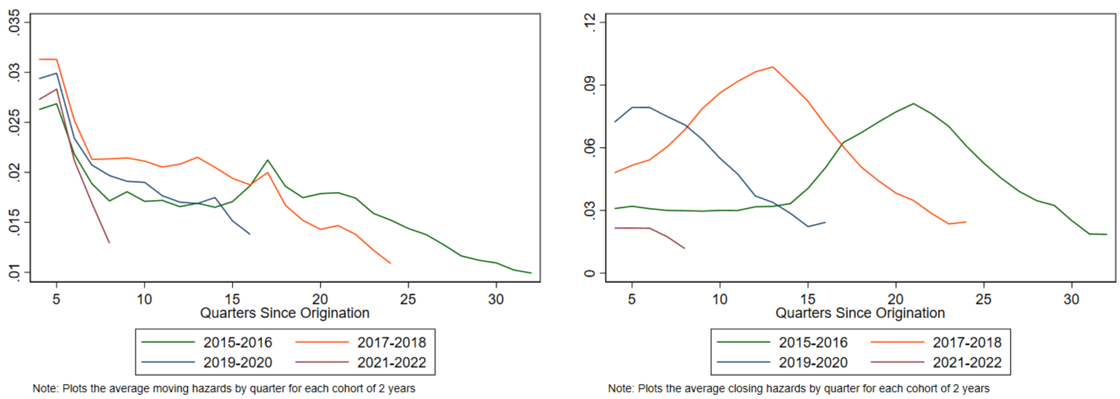
5 Main Results

5.1 Empirical Hazard Rates by Cohort

We begin with simple descriptives of the likelihood of moving and of closing mortgages. Let $O(i)$ represent the date on which mortgage i was originated, and let Y_i represent the duration from mortgage origination to a household's move out of the zip code, with $Y_i = \infty$ if the household never moves. The hazard that a household who originated a mortgage in quarter q moves in quarter $t > q$ is

$$\lambda(q,t) = Pr(Y_i = t - q \mid O(i) = q, Y_i > t - q - 1).$$

Figure 2: Empirical hazards of moving and closing mortgage, by time since mortgage initiation



Notes: Figures show ZIP code moving hazards by quarter since origination. The share of moving households at time t is calculated for each cohort as the share of households moving between $t-1$ and t divided by the share that have not moved at $t-1$.

The left panel of Figure 2 shows empirical estimates of this hazard rate, grouping together origination dates into four two-year "cohorts." For the earlier origination cohorts, the mobility hazard is high in the first two years after origination (i.e., for $t-q \leq 8$), then declines to a low but stable level thereafter. However, we see that each cohort mobility hazard turns down sharply near the end of the available data, a downturn that happens within the first eight quarters for the 2021-22 originations. The timing of the downturn corresponds to observations from calendar year 2022 or 2023, which in event time represent quarters 4-11 for 2021:Q1 originations but quarters 20-27 for 2017:Q1 originations.

The right panel of Figure 2 shows hazards for a different outcome, closing the mortgage. This can precede moves when mortgages are refinanced or simply prepaid. The profile here is different. There is a prominent peak in each series that corresponds to calendar times around 2020. We interpret this as reflecting large-scale refinancing in the low interest rate environment of 2019-2021. The hazard of mortgage closing then falls in 2022 and 2023.

5.2 Cox Model Estimates of Moving Hazard

To aggregate the different series in Figure 2 into a single quantitative estimate of the time profile of mobility, we fit a semi-parametric Cox hazard model. The Cox model specifies:

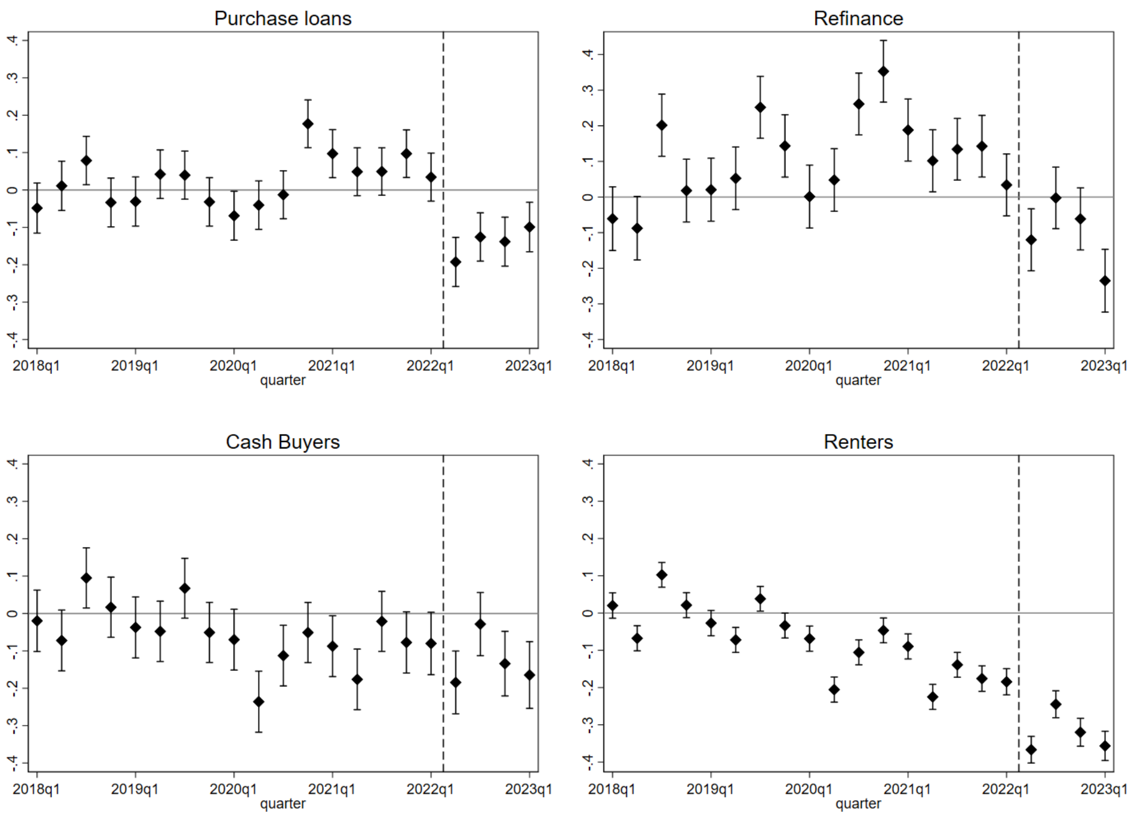
$$\lambda(q,t) = e^{\beta' X_{it}} \lambda_0(t-q). \tag{1}$$

where $\lambda_0(d)$ is a baseline hazard function.

We begin with a very flexible model that includes a full set of calendar time (t) indicators as X_{it}. The upper left panel of Figure 3 plots the estimated calendar time effects on mobility for new purchase loans. (The estimated baseline hazard function $\lambda_0(d)$ is plotted in the Appendix.) This shows a sharp dropoff in mobility hazards in 2022 and 2023. The timing of this dropoff lines up neatly with the rise in interest rates and the increase in predicted interest rate lock in Figure 1. The upper right panel shows coefficients from a similar model estimated on refinanced loans. The series is a bit noisier here, but also shows a substantial decline in 2022. The lower panels of Figure 3 plot estimates for two additional samples - homeowners without mortgages ("cash buyers") and renters. Neither of these show sharp changes in mobility rates in 2022 – both decline gradually over many years, but this trend does not seem to change in response to recent interest rate increases.

The pattern in Figure 3 clearly points to interest rate changes in 2022-23 as drivers of the decline in mobility of mortgage-holders in this period. To explore this, we move to a more parametric model that replaces calendar time effects with theoretically motivated measures of the disincentive to move. The discussion above in Section 2 suggests that interest rate lock will occur when current market rates exceed the rate at which a mortgage was originated, and will be more severe the larger the gap grows. Letting r_t represent the market rate at time t, the rate gap for mortgage i at time t is $g_{it} \equiv max(0, r_t - r_{d(i,t)})$, where $d(i,t)$ is the date at which the rate for mortgage i was fixed. We form two versions of g_{it}, corresponding to the two measures of a mortgage's rate discussed in Section 2. One uses the most recent refinance of a mortgage

Figure 3: Calendar time effects from Cox proportional hazards model, mortgage holders (left) and renters and non-mortgage-holding homeowners (right)



Notes: Calendar time effects are from estimates of Cox proportional hazard models where failure is mobility out of the ZIP code; all control for nonparametric baseline hazard in the elapsed time since the mortgage was originated $(t - O(i))$. Calendar time fixed effects are seasonally adjusted by subtracting the seasonal mean over the sample period.

to set $d(i, t)$, so that $r_{d(i,t)}$ represents an estimate of the rate actually paid on the mortgage at time t. (Because we use market rates, we abstract from idiosyncratic differences in the rates homeowners pay due to differences in loan-to-value ratios, borrower credit scores, and so on.) The other, which we label g^*, holds $d(i, t)$ fixed at the origination of the focal mortgage, so that $r_{d(i,t)}$ does not change if the focal mortgage is refinanced.

Table 4: Effects of interest rate gaps on mobility, varying samples

	Mortgages						Non-	
	All		Purchases		Refinances		mortgages	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Interest rate gap (> 0)	-0.154	-0.212	-0.139	-0.198	-0.164	-0.234	-0.0781	-0.0356
	(.00181)	(.00232)	(.00273)	(.00342)	(.00242)	(.00318)	(.00204)	(.00270)
Observations	21641699	21641699	7870777	7870777	13770922	13770922	7212447	7212447
Controls	N	Y	N	Y	N	Y	N	Y

Notes: Interest rate gap is the difference between the current market rate at time t and the market rate at the time the mortgage was last refinanced, g_{it}. Models are Cox proportional hazard models where failure is mobility out of the ZIP code; all control for nonparametric baseline hazard in the elapsed time since the mortgage was originated $(t - O(i))$. Controls in even-numbered columns are negative interest rate gaps $(min(0, r_t - r_{d(i,t)}))$; a linear trend in calendar time t; and a cubic in the change in home values in the ZIP code from the mortgage origination to present, with separate coefficients for positive and negative changes. “Purchases” are mortgages taken out to finance a new purchase (identified from households who move into the ZIP code around the time of origination. “Non-mortgages” includes cash buyers and renters; in each case, the interest rate gap is computed from the date that the household moved into the ZIP code.

The first two columns of Table 4 present coefficient estimates from (1). Odd numbered columns include just the baseline hazard as a control. Even numbered columns add controls for negative interest rate gaps (set to zero when the gap is positive), a linear trend in calendar time, and separate cubics in the change in log home values in the ZIP code from mortgage origination to present for positive and negative changes. We show results for several samples. Columns 1 and 2 show all mortgages, which are then broken into purchase mortgages and refinances in columns 3-6. Columns 7 and 8 show a separate sample of non-mortgages - renters and cash buyers.

We see consistent negative effects of rate gaps on mobility rates. The -0.154 coefficient in column 1 implies that a one percentage point increase in the rate gap (e.g., a rise in interest rates from 3% to 4%) reduces the probability that a homeowner moves in a quarter by $1 - e^{-0.154} = 14\%$. This is slightly smaller for mortgage purchases, and larger for refinances. While we also find a significant negative effect for non-mortgage-holders, it is less than one-quarter as large with controls, suggesting that the dynamics we identify in columns 1-6 are not driven by secular changes in mobility or other aspects of the housing market (e.g., changes in home values).

A potential concern is that our calculation of the rate gap g depends on the refinance history. If homeowners who do not intend to move are more likely to refinance in 2021 and therefore have lower rate gaps in 2022, this would contribute to a negative relationship between the rate gap and mobility even in the absence of a causal effect. To address this concern, Table 5 presents instrumental variables specifications that use g^* as an instrument for g. g^* is fixed when the mortgage is taken out and not updated later. Because the Cox model is nonlinear, we implement this with a control function approach, adding to the specification 1 a control for $g - E[g_{it} \mid g^*_{it}, X_{it}]$ (Palmer, 2022).[16] This reduces the coefficient on the rate gap, but it remains substantial. Again returning to the example of an increase in rates from 3% to 4%, the estimate in column 2 implies that this would reduce mobility rates for those holding mortgages

[16]The first stage relationship between g^* and g is reported in Appendix Table B.1. The reduced form relationship between g^* and mobility is reported in Appendix Table B.2.

at the original, lower rate by 5.4%.

Table 5: Instrumental variables estimates of the effects of interest rate gaps on mobility, varying samples

	Mortgages					
	All		Purchases		Refinances	
	(1)	(2)	(3)	(4)	(5)	(6)
Interest rate gap (> 0)	-0.125	-0.0551	-0.103	-0.0503	-0.141	-0.0705
	(.00182)	(.00270)	(.00275)	(.00400)	(.00243)	(.00373)
Observations	21641699	21641699	7870777	7870777	13770922	13770922
Controls	N	Y	N	Y	N	Y

Notes: Interest rate gap is the difference between the current market rate at time t and the market rate at the time the mortgage was last refinanced, g_{it}. Models are Cox proportional hazard models where failure is mobility out of the ZIP code; all control for nonparametric baseline hazard in the elapsed time since the mortgage was originated $(t - O(i))$. All models include a control function for the difference between g_{it} and its prediction given g^*_{it} and the other controls; thus, the interest rate gap coefficient is an instrumental variables estimate using g^*_{it} as the instrument. Controls in even-numbered columns are negative interest rate gaps $(min(0, r_t - r_{d(i,t)}))$; a linear trend in calendar time t; and a cubic in the change in home values in the ZIP code from the mortgage origination to present, with separate coefficients for positive and negative changes. “Purchases” are mortgages taken out to finance a new purchase (identified from households who move into the ZIP code around the time of origination.

5.3 Discussion

Using back-of-the-envelope calculations we can calculate the implications for the U.S. mortgage market and for U.S. household finances more generally. Instrumental variables estimates show that each percentage point difference between a household's interest rates and the prevailing rates reduces mobility by about 5.4 percent. The average interest rate gap for households with a mortgage was about 3 percentage points in our data in early 2023. Thus, our estimates imply that interest rate lock reduced mobility by about 15% for households with mortgages from what it would have been had rates remained at their 2021 levels — an effect size in line with the size of the mobility reduction visible in the event studies shown in Figure 3.

What do these estimates mean for aggregate mobility? One-quarter of Americans have a mortgage, and until 2020, about 3.3% of them moved out of their ZIP codes each quarter. But rate lock has been reducing mobility rates throughout the period since. A 15% reduction in quarterly mobility would reduce that 3.3% rate to 2.8%. This has cumulated (at somewhat varying rates) sinces rates began increasing in 2021. Our estimates imply that cumulated mobility of homeowners from 2020Q4 through 2023Q2 was approximately 8% (2.3 percentage points) lower than it would have been over this period in the absence of rate lock.

The magnitude of these estimates implies that aggregate mobility was reduced by interest rate lock. Because approximately one-quarter of households hold mortgages, 0.5 percentage point decline in their mobility rate decreased *overall* mobility by about one-eighth of a percentage point, or about 3% off of the pre-COVID average rate. On average, mobility has declined by a bit more than half over the last half century. The decline that we attribute to mortgage lock accelerated this secular decline by about one and a half years. These calculations leave out potentially important equilibrium effects coming from lower housing transaction volumes and higher search costs.

U.S. households saved money by not moving. In our data, the average mortgage in the first quarter of 2023 has a rates 3% below the rates available on new mortgages at that time. Thus, we estimate that the moving hazard was reduced by 15% for households with a mortgage. This reduction in mobility has prevented average rates paid from rising as quickly as they would have. Our estimates imply that the average rate paid on open mortgages is about 8 basis points lower than it would have been had mobility rates been maintained at their zero-rate-lock levels.

The average mortgage size in the first quarter of 2023 was $232,000. Households deterred from moving avoided a 3 percent increase in interest rates, or $6,960 dollars per year for the average balance. The aggregate savings was also large. The size of the U.S. mortgage market was around $12 trillion in early 2023. If 2.3% of households with a mortgage were deterred from moving by high interest rates, the resulting annual savings was just over $8 billion.

6 Concluding Remarks

We estimate that interest rate lock has a substantial effect on individuals' propensity to move ZIP codes. Our preferred specification is a Cox proportional hazard specification that models ZIP code moving probability as a function of the gap between the rate a household is paying for its mortgage and the current prevailing mortgage rate. The Cox model implicitly controls for the baseline hazard rate, which is modeled as a function of the time since a household has a mortgage.

Our preferred estimates come from instrumental variables models which instrument for the interest rate on a mortgage using the prevailing rate at the time of mortgage origination. The IV specifications show that each percentage point increase in the gap between the mortgage's rates and prevailing rates reduces mobility between 5% and 12%. When we repeat the specifications for individuals without a mortgage, such as renters and non-mortgaged homeowners, the estimates are much smaller. Therefore we think that macroeconomic conditions or other omitted variables do not explain our results.

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Appendix

A Detailed Data Construction

A.1 Main Sample

Our main analysis sample is a panel of households with mortgages. To track mobility for these households, we first identify unique mortgages, defined as mortgages originated by a particular borrower for a specific principal amount on a specific date. We drop mortgages which are duplicated in the credit records and match these mortgages to the panel of households. For each mortgage, we track the ZIP code of the household for the subsequent forty quarters. We also include information on the household's total number of mortgages, debt, and data as of the origination date, such as the loan origination amount. Using data 40 quarters after mortgage origination ensures that we continue to track households who refinance their mortgage or prepay for other reasons. Including these individuals is important for our empirical strategy. The decision to prepay is an endogenous result of ex post mortgage rates, so excluding households that refinance would lead to sample attrition that is correlated with the outcomes of interest.

We count loans taken out to refinance an earlier mortgage as new mortgages. Each new mortgage begins a new spell. This means that a household can have several overlapping spells - one beginning when it originally purchases the home and others beginning each time it refinances. We select one at random for each household to ensure that observations are not dependent and that our sample appropriately represents purchase loans and refinances.

A.2 Credit Registry Variables

We measure moving using an indicator variable if an individual changes ZIP codes. The UC-CCP data also contains census tract and block information for most households starting in

2010. Identifying census tract moves would be an alternative way to measure mobility but we prefer to use ZIP codes because it is available for all households. Also, mobility measurement is more difficult with census block information because census block codes change over time to reflect changing census definitions. About one-third of moves across census tracts do not result in a change in ZIP code, so we will miss these moves. However, aggregate patterns of ZIP code and census block moves are very similar, so we think our findings are likely to generalize to other levels of geography.

To distinguish between renters and homeowners without a mortgage, we rely on a UC-CCP field that identifies known homeowners from public records data. Of people who do not have a mortgage at the beginning of a spell in a ZIP code, we label those who are identified at that point as homeowners as cash buyers, and those who are never identified as homeowners as renters. (Spells that start as non-homeowners but transition within the spell to be homeowners are excluded.)

B Additional Tables and Figures

In this appendix we present several additional results. Table B.1 presents the first-stage relationship between the interest rate gap calculated based on the origination rate, g^*, and the gap calculated from the rate that applies to the most recent refinance, g. We implement this as an OLS regression applied to the panel of mortgage-by-quarter observations, with mortgages excluded after the borrower leaves the ZIP code, and we cluster standard errors at the mortgage level. Table B.2 shows a kind of "reduced form" model that uses g^* directly in the Cox model in place of g.

Tables B.3 and B.4 present a robustness check where mortgages originated in 2020 or therafter are excluded, first in OLS specifications and then IV.

Table B.1: First stage relationship between interest rate gap relative to origination rate (g^*) and gap relative to most recent refinance (g)

	Mortgages					
	All		Purchases		Refinances	
	(1)	(2)	(3)	(4)	(5)	(6)
Predicted interest rate gap (> 0)	1.047	0.979	1.063	0.981	1.039	0.978
	(.00006)	(.00008)	(.0001)	(.00013)	(.00007)	(.00009)
Observations	37630691	37630691	13704772	13704772	23925919	23925919
Controls	N	Y	N	Y	N	Y

Notes: Models are OLS regressions of the rate gap g_{it}, computed as the difference between the current market rate and the market rate at the time of the last refinance, on the predicted rate gap g^*_{it}, the difference between the current market rate at time t and the market rate at the time the mortgage was originated. In each case, the gap is split into separate variables for positive and negative values; the positive value is shown here. Sample is a panel of mortgages, with each mortgage retained until the borrower moves from the zip code; standard errors are clustered on the borrower.

Table B.2: Reduced-form effects of effect of interest rate gap relative to origination rate (g^*) on mobility

	Mortgages					
	All		Purchases		Refinances	
	(1)	(2)	(3)	(4)	(5)	(6)
Predicted interest rate gap (> 0)	-0.095	-0.0401	-0.0734	-0.0435	-0.108	-0.0477
	(.00185)	(.00264)	(.00285)	(.00394)	(.00244)	(.00362)
Observations	21641699	21641699	7870777	7870777	13770922	13770922
Controls	N	Y	N	Y	N	Y

Notes: Predicted interest rate gap is the difference between the current market rate at time t and the market rate at which a mortgage was originated, g^*_{it}. Models are Cox proportional hazard models where failure is mobility out of the ZIP code; all control for nonparametric baseline hazard in the elapsed time since the mortgage was originated ($t - O(i)$). Controls in even-numbered columns are negative interest rate gaps ($min(0, r_t - r_{d(i,t)})$); a linear trend in calendar time t; and a cubic in the change in home values in the ZIP code from the mortgage origination to present, with separate coefficients for positive and negative changes. "Purchases" are mortgages taken out to finance a new purchase (identified from households who move into the ZIP code around the time of origination.

Table B.3: Effects of interest rate gaps on mobility, pre-COVID samples

	Mortgages Originated before 2020					
	All		Purchases		Refinances	
	(1)	(2)	(3)	(4)	(5)	(6)
Interest rate gap (> 0)	-0.196	-0.288	-0.200	-0.265	-0.194	-0.304
	(.00260)	(.00314)	(.00372)	(.00448)	(.00363)	(.00440)
Observations	18642771	18642771	6936958	6936958	11705813	11705813
Controls	N	Y	N	Y	N	Y

Notes: Interest rate gap is the difference between the current market rate at time t and the market rate at the time the mortgage was last refinanced, g_{it}. Models are Cox proportional hazard models where failure is mobility out of the ZIP code; all control for nonparametric baseline hazard in the elapsed time since the mortgage was originated $(t - O(i))$. Controls in even-numbered columns are negative interest rate gaps $(min(0, r_t - r_{d(i,t)}))$; a linear trend in calendar time t; and a cubic in the change in home values in the ZIP code from the mortgage origination to present, with separate coefficients for positive and negative changes. “Purchases” are mortgages taken out to finance a new purchase (identified from households who move into the ZIP code around the time of origination. “Non-mortgages” includes cash buyers and renters; in each case, the interest rate gap is computed from the date that the household moved into the ZIP code.

Table B.4: Instrumental variables estimates of the effects of interest rate gaps on mobility, pre-COVID samples

	Mortgages					
	All		Purchases		Refinances	
	(1)	(2)	(3)	(4)	(5)	(6)
Interest rate gap (> 0)	-0.147	-0.100	-0.147	-0.0754	-.0150	-0.117
	(.00269)	(.00386)	(.00385)	(.00553)	(.00375)	(.00540)
Observations	18642771	18642771	6936958	6936958	11705813	11705813
Controls	N	Y	N	Y	N	Y

Notes: Interest rate gap is the difference between the current market rate at time t and the market rate at the time the mortgage was last refinanced, g_{it}. Models are Cox proportional hazard models where failure is mobility out of the ZIP code; all control for nonparametric baseline hazard in the elapsed time since the mortgage was originated $(t - O(i))$. All models include a control function for the difference between g_{it} and its prediction given g^*_{it} and the other controls; thus, the interest rate gap coefficient is an instrumental variables estimate using g^*_{it} as the instrument. Controls in even-numbered columns are negative interest rate gaps $(min(0, r_t - r_{d(i,t)}))$; a linear trend in calendar time t; and a cubic in the change in home values in the ZIP code from the mortgage origination to present, with separate coefficients for positive and negative changes. "Purchases" are mortgages taken out to finance a new purchase (identified from households who move into the ZIP code around the time of origination.